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HOOKE'S MICROGRAPHIA

PROFESSOR LORANDE LOSS WOODRUFF
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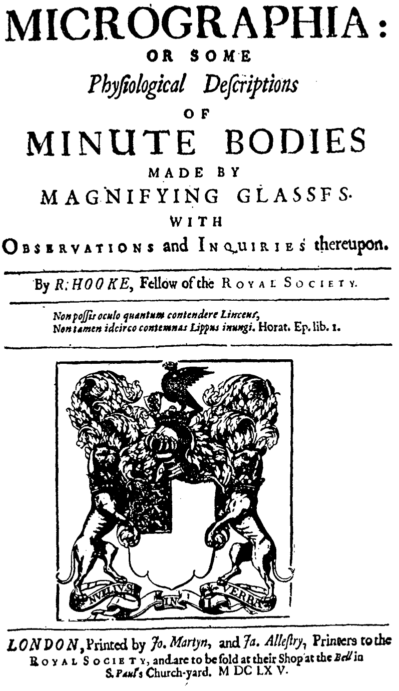
BIOLOGICAL research in general during the latter part of the seventeenth century begins to be permeated with an attention to details and with an intensive critical analysis which is conspicuous by its absence in practically all but the masterpieces of previous times. Nor is the explanation far to seek. The improvement of simple lenses and the invention of the compound microscope provided a method of increasing the apparent size of things which, in addition to revealing a new world of "animalcules" beyond the range of unaided vision, brought to the attention of students finer details of structure of the higher animals and plants. But, as Sachs has emphasized, the use of magnifying glasses contributed an advantage of still another kind—it taught those who employed them to see scientifically and exactly. In equipping the eye with increased powers the attention was concentrated on definite points and observation had to be accompanied by conscious critical reflection in order to make the object, which is observed in part only by the microscope, clear to the mental eye in all the relations of the parts to each other and to the whole. Therefore, in marked contrast with the very slow progress in obtaining a mental mastery over the macroscopic morphological features of plants and animals is the work of the early students with the microscope such as Hooke and Grew in England, Malpighi in Italy, and Swammerdam and Leeuwenhoek in Holland.

The earliest clear appreciation of the importance of studying nature with instruments which increase the powers of the senses in general and the vision in particular, is found in a remarkable book by a remarkable man—the "Micrographia" of Robert Hooke, published by the Royal Society of London in 1665 (cf. Fig. 1). The point of view of the author is well illustrated in the following extracts from the preface:

> *It is the great prerogative of Mankind above other Creatures, that we are not only able to* behold *the works of Nature, or barely to* sustein *our lives by them, but we have also the power of* considering, comparing, altering, assisting, *and* improving *them to various uses. And as this is the peculiar priviledge of humane Nature in general, so it is capable of being so far advanced by the helps of Art, and Experience, as to make some Men excel others in their Observations, and Deductions, almost as much as they do Beasts. By the addition of such* artificial Instruments *and* methods, *there may be, in some manner, a reparation made for the mischiefs, and imperfection, mankind has drawn upon it self, by negligence, and intemperance, and a wilful and superstitious deserting the Prescripts and Rules of Nature, whereby every man, both from a deriv'd corruption, innate and born with him, and from his breeaing and converse with men, is very subject to slip into all sorts of errors.*



MICROGRAPHIA:
OR SOME
Phyſiological Deſcriptions
OF
MINUTE BODIES
MADE BY
MAGNIFYING GLASSES.
WITH
OBSERVATIONS and INQUIRIES thereupon.

By *R: HOOKE*, Fellow of the ROYAL SOCIETY.

Non poſſis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. lib. 1.

LONDON, Printed by *Jo. Martyn*, and *Ja. Alleſtry*, Printers to the
ROYAL SOCIETY, and are to be ſold at their Shop at the *Bell* in
S. *Paul's* Church-yard. M DC LX V.

FIG. 1.

. . . .

The next care to be taken, in respect of the Senses, is a supplying of their infirmities with Instruments, *and, as it were, the adding of* artificial Organs *to the* natural; *this in one of them has been of late years accomplisht with prodigious benefit to all sorts of useful knowledge, by the invention of Optical Glasses. By the means of* Telescopes, *there is nothing so* far distant *but may be represented to our view; and by the help of* Microscopes, *there is nothing so* small, *as to escape our inquiry; hence there is a new visible World discovered to the understanding. By this means the Heavens are open'd, and a vast number of new Stars, and new Motions, and new Productions appear in them, to which all the antient Astronomers were utterly Strangers. By this the Earth it self, which lyes so neer us, under our feet, shews quite a new thing to us, and in every* little particle *of its matter, we now behold almost as great a variety of Creatures, as we were able before to reckon up in the whole* Universe *it self.*

It seems not improbable, but that by these helps the subtilty of the composition of Bodies, the structure of their parts, the various texture of their matter, the instruments and manner of their inward motions, and all the other possible appearances of things, may come to be more fully discovered; all which the antient Peripateticks *were content to comprehend in two general and (unless further explain'd) useless words of* Matter *and* Form. *From whence there may arise many admirable advantages, towards the increase of the* Operative, *and the* Mechanick *Knowledge, to which this Age seems so much inclined, because we may perhaps be inabled to discern all the secret workings of Nature, almost*

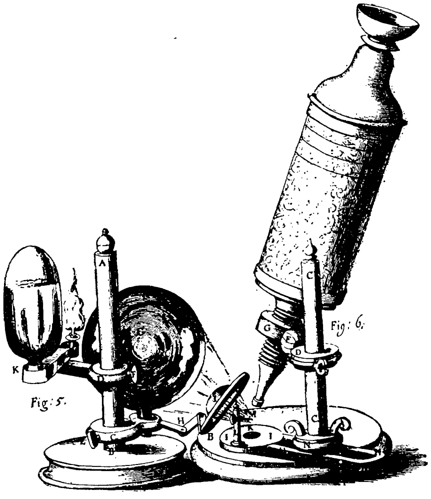


FIG. 2.

> *in the same manner as we do those that are the productions of Art, and are manag'd by Wheels, and Engines, and Springs, that were devised by humane Wit.*
>
> *In this kind I here present to the World my imperfect Indeavours; which though they shall prove no other way considerable, yet, I hope, they may be in some measure useful to the main Design of a* reformation *in Philosophy. . . .*
>
> . . . .
>
> *As for my part, I have obtained my end, if these my small Labours shall be thought fit to take up some place in the large stock of* natural Observations, *which so many hands are busie in providing. If I have contributed the* meanest foundations *whereon others may raise nobler* Superstructures, *I am abundantly satisfied; and all my ambition is, that I may serve to the great Philosophers of this Age, as the makers and the grinders of my Glasses did to me; that I may prepare and furnish them with some* Materials, *which they may afterwards order and manage with better skill, and to far greater advantage.*
>
> . . . .
>
> *Toward the prosecution of this method in* Physical Inquiries, *I have here and there* gleaned *up an* handful *of Observations, in the collection of most of which I made use of* Microscopes, *and some other* Glasses *and* Instruments *that improve the sense; which way I have herein taken, not that there are not multitudes of useful and pleasant Observables, yet uncollected, obvious enough without helps of Art, but only to promote the use of Mechanical helps for the Senses, both in the surveying the already visible World, and for the discovery of many others hitherto unknown, and to make us, with the great Conqueror, to be affected that we have not yet overcome one World when there are so many others to be discovered, every considerable improvemnt* of Telescopes *or* Microscopes *producing new Worlds and* Terra-Incognita's *to our view.*

The author of this work was a versatile genius who applied his powers to a wide field of endeavor—physics, chemistry, mathematics, mechanics, architecture and philosophy—fields which long since have expanded beyond the grasp of one man, and which, even in his own time and by himself, might more profitably have been coped with singly. It is impossible to adequately survey Hooke's varied career within the limits imposed by this paper, but the following extracts from his biography, appended by Richard Waller to Hooke's "Posthumous Works," show what manner of man he was (cf. Fig. 5).

Dr. *Robert Hooke* was Born at *Freshwater,* a Peninsula on the West side of the Isle of *Wight,* on the eighteenth of *July,* being *Saturday,* 1635, at twelve a Clock at Noon, and Christened the twenty sixth following by his own Father Minister of that Parish.

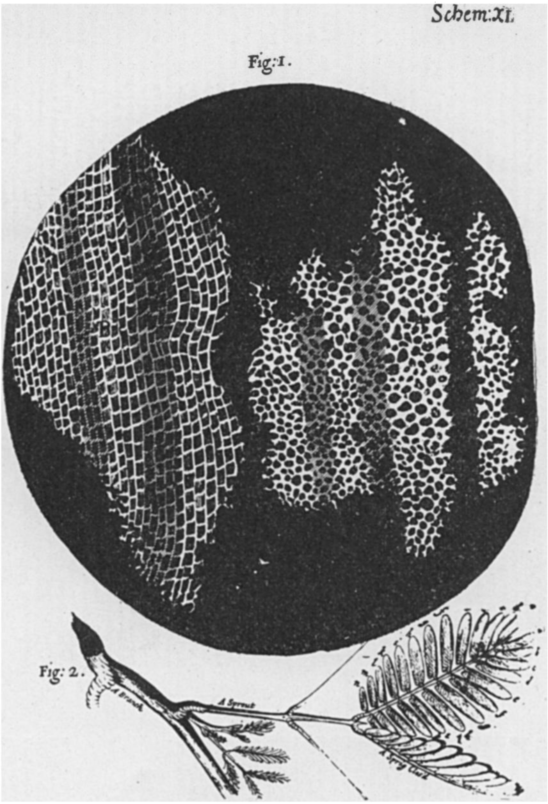
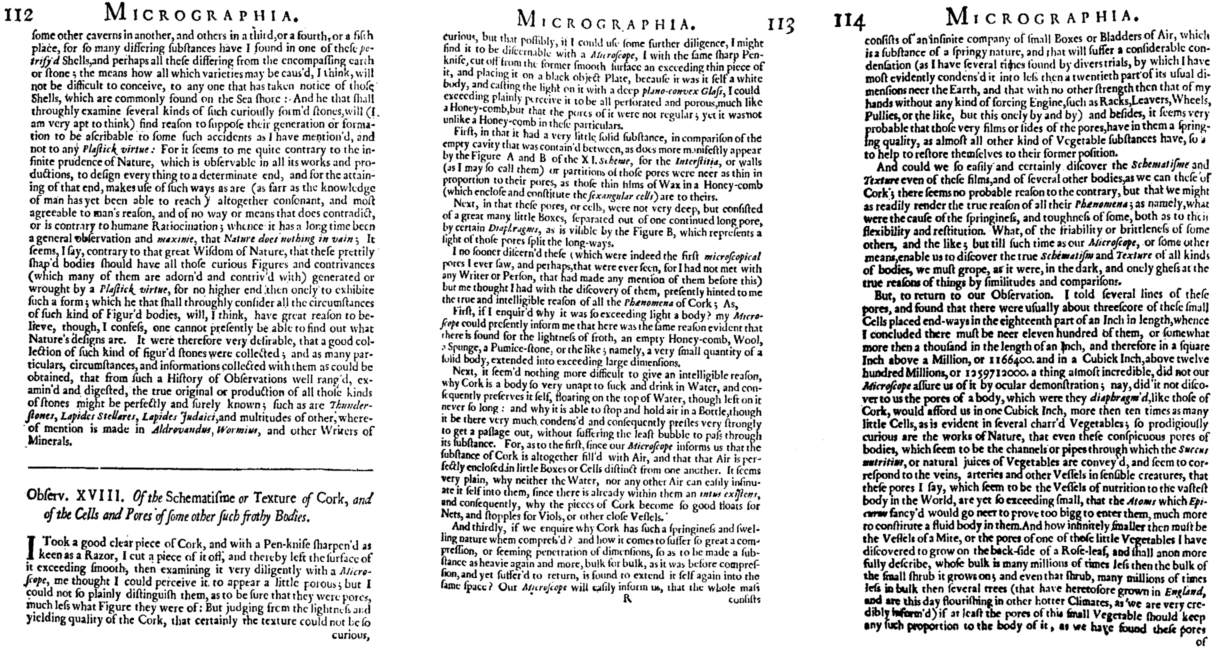

Schem: XI.
Fig: 1.
Fig: 2.
A Branch
A Sprout
A Sprig Cluck

FIG. 3.

. . . .

From *Westminster-School* he went to the University of *Oxford,* in 1653. but as 'tis often the Fate of Persons great in Learning to be small in other Circumstances, his were but mean. I find that he was a Student of *Christ-Church,* tho' not of the Foundation, but was, as I have heard, a Servitor of one Mr. *Goodman,* and took his Degree of *Master of Arts* several Years after, about 1662, or 1663.

About the Year 1655, he began to shew himself to the World, and that he had not spent his Juvenile Years in vain; for there being a Concourse at that time of extraordinary Persons at *Oxford,* each of which afterwards were particularly distinguish'd for the great Light



ſome other caverns in another, and others in a third, or a fourth, or a fifth place, for ſo many differing ſubſtances have I found in one of theſe *petrify'd* Shells, and perhaps all theſe differing from the encompaſſing earth or ſtone; the means how all which varieties may be cauſ'd, I think, will not be difficult to conceive, to any one that has taken notice of thoſe Shells, which are commonly found on the Sea ſhore: And he that ſhall throughly examine ſeveral kinds of ſuch curiouſly form'd ſtones, will (I am very apt to think) find reaſon to ſuppoſe their generation or formation to be aſcribable to ſome ſuch accidents as I have mention'd, and not to any *Plaſtick virtue:* For it ſeems to me quite contrary to the infinite prudence of Nature, which is obſervable in all its works and productions, to deſign every thing to a determinate end, and for the attaining of that end, makes uſe of ſuch ways as are (as farr as the knowledge of man has yet been able to reach) altogether conſonant, and moſt agreeable to man's reaſon, and of no way or means that does contradict, or is contrary to humane Ratiocination; whence it has a long time been a general obſervation and *maxime*, that *Nature does nothing in vain*; It ſeems, I ſay, contrary to that great Wiſdom of Nature, that theſe prettily ſhap'd bodies ſhould have all thoſe curious Figures and contrivances (which many of them are adorn'd and contriv'd with) generated or wrought by a *Plaſtick virtue*, for no higher end then onely to exhibite ſuch a form; which he that ſhall throughly conſider all the circumſtances of ſuch kind of Figur'd bodies, will, I think, have great reaſon to believe, though, I confeſs, one cannot preſently be able to find out what Nature's deſigns are. It were therefore very deſirable, that a good collection of ſuch kind of figur'd ſtones were collected; and as many particulars, circumſtances, and informations collected with them as could be obtained, that from ſuch a Hiſtory of Obſervations well rang'd, examin'd and digeſted, the true original or production of all thoſe kinds of ſtones might be perfectly and ſurely known; ſuch as are *Thunder-ſtones*, *Lapides Stellares*, *Lapides Judaici*, and multitudes of other, whereof mention is made in *Aldrovandus*, *Wormius*, and other Writers of Minerals.

Obſerv. XVIII. *Of the* Schematiſme *or* Texture *of* Cork, *and of the Cells and Pores of ſome other ſuch frothy Bodies.*

I Took a good clear piece of Cork, and with a Pen-knife ſharpen'd as keen as a Razor, I cut a piece of it off, and thereby left the ſurface of it exceeding ſmooth, then examining it very diligently with a *Microſcope*, me thought I could perceive it to appear a little porous; but I could not ſo plainly diſtinguiſh them, as to be ſure that they were pores, much leſs what Figure they were of: But judging from the lightneſs and yielding quality of the Cork, that certainly the texture could not be ſo

curious,

curious, but that poſſibly, if I could uſe ſome further diligence, I might find it to be diſcernable with a *Microſcope*, I with the ſame ſharp Penknife, cut off from the former ſmooth ſurface an exceeding thin piece of it, and placing it on a black object Plate, becauſe it was it ſelf a white body, and caſting the light on it with a deep *plano-convex Glaſs*, I could exceeding plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular; yet it was not unlike a Honey-comb in theſe particulars.

Firſt, in that it had a very little ſolid ſubſtance, in compariſon of the empty cavity that was contain'd between, as does more manifeſtly appear by the Figure A and B of the XI. *Scheme*, for the *Interſtitia*, or walls (as I may ſo call them) or partitions of thoſe pores were neer as thin in proportion to their pores, as thoſe thin films of Wax in a Honey-comb (which encloſe and conſtitute the *ſexangular cells*) are to theirs.

Next, in that theſe pores, or cells, were not very deep, but conſiſted of a great many little Boxes, ſeparated out of one continued long pore, by certain *Diaphragms*, as is viſible by the Figure B, which repreſents a ſight of thoſe pores ſplit the long-ways.

I no ſooner diſcern'd theſe (which were indeed the firſt *microſcopical* pores I ever ſaw, and perhaps, that were ever ſeen, for I had not met with any Writer or Perſon, that had made any mention of them before this) but me thought I had with the diſcovery of them, preſently hinted to me the true and intelligible reaſon of all the *Phænomena* of Cork; As,

Firſt, if I enquir'd why it was ſo exceeding light a body? my *Microſcope* could preſently inform me that here was the ſame reaſon evident that there is found for the lightneſs of froth, an empty Honey-comb, Wool, a Spunge, a Pumice-ſtone, or the like; namely, a very ſmall quantity of a ſolid body, extended into exceeding large dimenſions.

Next, it ſeem'd nothing more difficult to give an intelligible reaſon, why Cork is a body ſo very unapt to ſuck and drink in Water, and conſequently preſerves it ſelf, floating on the top of Water, though left on it never ſo long: and why it is able to ſtop and hold air in a Bottle, though it be there very much condens'd and conſequently preſſes very ſtrongly to get a paſſage out, without ſuffering the leaſt bubble to paſs through its ſubſtance. For, as to the firſt, ſince our *Microſcope* informs us that the ſubſtance of Cork is altogether fill'd with Air, and that that Air is perfectly encloſed in little Boxes or Cells diſtinct from one another. It ſeems very plain, why neither the Water, nor any other Air can eaſily inſinuate it ſelf into them, ſince there is already within them an *intus exiſtens*, and conſequently, why the pieces of Cork become ſo good floats for Nets, and ſtopples for Viols, or other cloſe Veſſels.

And thirdly, if we enquire why Cork has ſuch a ſpringineſs and ſwelling nature whem compreſs'd? and how it comes to ſuffer ſo great a compreſſion, or ſeeming penetration of dimenſions, ſo as to be made a ſubſtance as heavie again and more, bulk for bulk, as it was before compreſſion, and yet ſuffer'd to return, is found to extend it ſelf again into the ſame ſpace? Our *Microſcope* will eaſily inform us, that the whole maſs

R consiſts

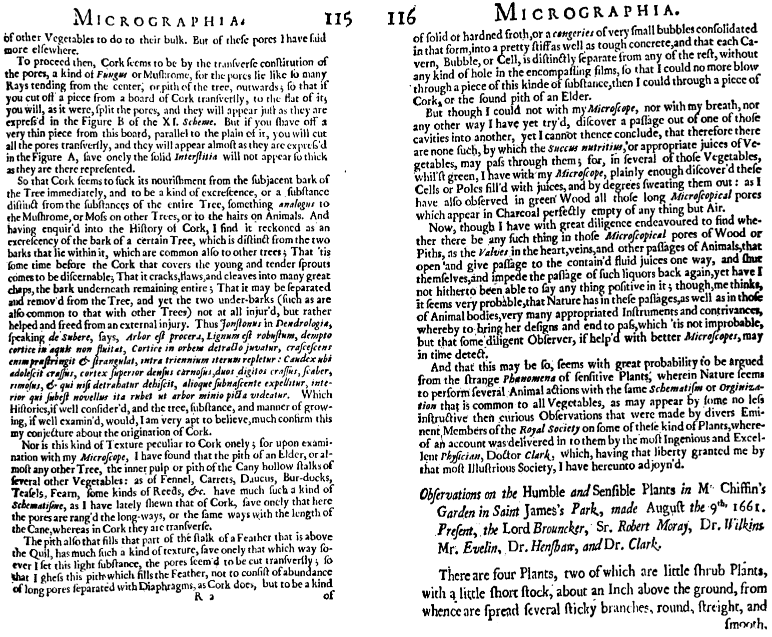
conſiſts of an infinite company of ſmall Boxes or Bladders of Air, which is a ſubſtance of a ſpringy nature, and that will ſuffer a conſiderable condenſation (as I have ſeveral times found by divers trials, by which I have moſt evidently condens'd it into leſs then a twentieth part of its uſual dimenſions neer the Earth, and that with no other ſtrength then that of my hands without any kind of forcing Engine, ſuch as Racks, Leavers, Wheels, Pullies, or the like, but this onely by and by) and beſides, it ſeems very probable that thoſe very films or ſides of the pores, have in them a ſpringing quality, as almoſt all other kind of Vegetable ſubſtances have, ſo as to help to reſtore themſelves to their former poſition.

And could we ſo eaſily and certainly diſcover the *Schematiſme* and *Texture* even of theſe films, and of ſeveral other bodies, as we can theſe of Cork; there ſeems no probable reaſon to the contrary, but that we might as readily render the true reaſon of all their *Phænomena*; as namely, what were the cauſe of the ſpringineſs, and toughneſs of ſome, both as to their flexibility and reſtitution. What, of the friability or brittleneſs of ſome others, and the like; but till ſuch time as our *Microſcope*, or ſome other means, enable us to diſcover the true *Schematiſm* and *Texture* of all kinds of bodies, we muſt grope, as it were, in the dark, and onely gheſs at the true reaſons of things by ſimilitudes and compariſons.

But, to return to our Obſervation. I told ſeveral lines of theſe pores, and found that there were uſually about threeſcore of theſe ſmall Cells placed end-ways in the eighteenth part of an Inch in length, whence I concluded there muſt be neer eleven hundred of them, or ſomewhat more then a thouſand in the length of an Inch, and therefore in a ſquare Inch above a Million, or 1166400. and in a Cubick Inch, above twelve hundred Millions, or 1259712000. a thing almoſt incredible, did not our *Microſcope* aſſure us of it by ocular demonſtration; nay, did it not diſcover to us the pores of a body, which were they *diaphragm'd*, like thoſe of Cork, would afford us in one Cubick Inch, more then ten times as many little Cells, as is evident in ſeveral charr'd Vegetables; ſo prodigiouſly curious are the works of Nature, that even theſe conſpicuous pores of bodies, which ſeem to be the channels or pipes through which the *Succus nutritius*, or natural juices of Vegetables are convey'd, and ſeem to correſpond to the veins, arteries and other Veſſels in ſenſible creatures, that theſe pores I ſay, which ſeem to be the Veſſels of nutrition to the vaſteſt body in the World, are yet ſo exceeding ſmall, that the *Atoms* which *Epicurus* fancy'd would go neer to prove too bigg to enter them, much more to conſtitute a fluid body in them. And how infinitely ſmaller then muſt be the Veſſels of a Mite, or the pores of one of theſe little Vegetables I have diſcovered to grow on the back-ſide of a Roſe-leaf, and ſhall anon more fully deſcribe, whoſe bulk is many millions of times leſs then the bulk of the ſmall ſhrub it grows on; and even that ſhrub, many millions of times leſs in bulk then ſeveral trees (that have heretofore grown in *England*, and are this day flouriſhing in other hotter Climates, as we are very credibly inform'd) if at leaſt the pores of this ſmall Vegetable ſhould keep any ſuch proportion to the body of it, as we have found theſe pores

of

FIG. 4. (PART 1.)



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of other Vegetables to do to their bulk. But of theſe pores I have ſaid more elſewhere.

To proceed then, Cork ſeems to be by the tranſverſe conſtitution of the pores, a kind of *Fungus* or Muſhrome, for the pores lie like ſo many Rays tending from the center, or pith of the tree, outwards; ſo that if you cut off a piece from a board of Cork tranſverſly, to the flat of it, you will, as it were, ſplit the pores, and they will appear juſt as they are expreſs'd in the Figure B of the XI. *Scheme*. But if you ſhave off a very thin piece from this board, parallel to the plain of it, you will cut all the pores tranſverſly, and they will appear almoſt as they are expreſs'd in the Figure A, ſave onely the ſolid *Interſtitia* will not appear ſo thick as they are there repreſented.

So that Cork ſeems to ſuck its nouriſhment from the ſubjacent bark of the Tree immediately, and to be a kind of excreſcence, or a ſubſtance diſtinct from the ſubſtances of the entire Tree, ſomething *analogus* to the Muſhrome, or Moſs on other Trees, or to the hairs on Animals. And having enquir'd into the Hiſtory of Cork, I find it reckoned as an excreſcency of the bark of a certain Tree, which is diſtinct from the two barks that lie within it, which are common alſo to other trees; That 'tis ſome time before the Cork that covers the young and tender ſprouts comes to be diſcernable; That it cracks, flaws, and cleaves into many great chaps, the bark underneath remaining entire; That it may be ſeparated and remov'd from the Tree, and yet the two under-barks (ſuch as are alſo common to that with other Trees) not at all injur'd, but rather helped and freed from an external injury. Thus *Jonſtonus* in *Dendrologia*, ſpeaking *de Subere*, ſays, *Arbor eſt procera, Lignum eſt robuſtum, dempto cortice in aquis non fluitat, Cortice in orbem detracto juvatur, craſceſcens enim præſtringit & ſtrangulat, intra triennium iterum repletur: Caudex ubi adoleſcit craſſus, cortex ſuperior denſus carnoſus, duos digitos craſſus, ſcaber, rimoſus, & qui niſi detrahatur dehiſcit, alioque ſubnaſcente expellitur, interior qui ſubeſt novellus ita rubet ut arbor minio picta videatur.* Which Hiſtories, if well conſider'd, and the tree, ſubſtance, and manner of growing, if well examin'd, would, I am very apt to believe, much confirm this my conjecture about the origination of Cork.

Nor is this kind of Texture peculiar to Cork onely; for upon examination with my *Microſcope*, I have found that the pith of an Elder, or almoſt any other Tree, the inner pulp or pith of the Cany hollow ſtalks of ſeveral other Vegetables: as of Fennel, Carrets, Daucus, Bur-docks, Teaſels, Fearn, ſome kinds of Reeds, *&c.* have much ſuch a kind of *Schematiſme*, as I have lately ſhewn that of Cork, ſave onely that here the pores are rang'd the long-ways, or the ſame ways with the length of the Cane, whereas in Cork they are tranſverſe.

The pith alſo that fills that part of the ſtalk of a Feather that is above the Quil, has much ſuch a kind of texture, ſave onely that which way ſoever I ſet this light ſubſtance, the pores ſeem'd to be cut tranſverſly; ſo that I gheſs this pith which fills the Feather, not to conſiſt of abundance of long pores ſeparated with Diaphragms, as Cork does, but to be a kind

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of ſolid or hardned froth, or a *congeries* of very ſmall bubbles conſolidated in that form, into a pretty ſtiff as well as tough concrete, and that each Cavern, Bubble, or Cell, is diſtinctly ſeparate from any of the reſt, without any kind of hole in the encompaſſing films, ſo that I could no more blow through a piece of this kinde of ſubſtance, then I could through a piece of Cork, or the ſound pith of an Elder.

But though I could not with my *Microſcope*, nor with my breath, nor any other way I have yet try'd, diſcover a paſſage out of one of thoſe cavities into another, yet I cannot thence conclude, that therefore there are none ſuch, by which the *Succus nutritius*, or appropriate juices of Vegetables, may paſs through them; for, in ſeveral of thoſe Vegetables, whil'ſt green, I have with my *Microſcope*, plainly enough diſcover'd theſe Cells or Poles fill'd with juices, and by degrees ſweating them out: as I have alſo obſerved in green Wood all thoſe long *Microſcopical* pores which appear in Charcoal perfectly empty of any thing but Air.

Now, though I have with great diligence endeavoured to find whether there be any ſuch thing in thoſe *Microſcopical* pores of Wood or Piths, as the *Valves* in the heart, veins, and other paſſages of Animals, that open and give paſſage to the contain'd fluid juices one way, and ſhut themſelves, and impede the paſſage of ſuch liquors back again, yet have I not hitherto been able to ſay any thing poſitive in it; though, me thinks, it ſeems very probable, that Nature has in theſe paſſages, as well as in thoſe of Animal bodies, very many appropriated Inſtruments and contrivances, whereby to bring her deſigns and end to paſs, which 'tis not improbable, but that ſome diligent Obſerver, if help'd with better *Microſcopes*, may in time detect.

And that this may be ſo, ſeems with great probability to be argued from the ſtrange *Phænomena* of ſenſitive Plants, wherein Nature ſeems to perform ſeveral Animal actions with the ſame *Schematiſm* or *Orginization* that is common to all Vegetables, as may appear by ſome no leſs inſtructive then curious Obſervations that were made by divers Eminent Members of the *Royal Society* on ſome of theſe kind of Plants, whereof an account was delivered in to them by the moſt Ingenious and Excellent *Phyſician*, Doctor *Clark*, which, having that liberty granted me by that moſt Illuſtrious Society, I have hereunto adjoyn'd.

Obſervations on the Humble *and* Senſible Plants *in* M^{r} Chiffin's *Garden in Saint* James's *Park*, *made* Auguſt *the* 9th, 1661. *Preſent*, *the* Lord *Brouncker*, Sr. *Robert Moray*, Dr. *Wilkins* Mr. *Evelin*, Dr. *Henſhaw*, *and* Dr. *Clark*.

There are four Plants, two of which are little ſhrub Plants, with a little ſhort ſtock, about an Inch above the ground, from whence are ſpread ſeveral ſticky branches, round, ſtreight, and

ſmooth,

FIG. 4. (PART 2.)

they gave the Learned World by their justly admired Labours; he was soon taken notice of, and for his Facility in Mechanick Inventions much priz'd by them.

. . . .

"The same Year I contriv'd and made many trials about the Art of flying in the Air, and moving very swift on the Land and Water, of which I shew'd several Designs to Dr. *Wilkins* then *Warden* of *Wadham College,* and at the same time made a Module, which, by the help of Springs and Wings, rais'd and sustain'd itself in the Air; but finding by my own trials, and afterwards by Calculation, that the Muscles of a Mans Body were not sufficient to do anything considerable of that kind, I apply'd my Mind to contrive a way to make artificial Muscles; divers designs whereof I shew'd also at the same time to Dr. *Wilkins,* but was in many of my Trials frustrated of my expectations."[1]

What is mentioned here of his attempts about flying, is confirm'd by several Draughts and Schemes upon Paper, of the Methods that might be attempted for that purpose, and of some contrivances for fastening succedaneous Wings, not unlike those of Bats, to the Arms and Legs of a Man, as likewise of a Contrivance to raise him up by means of Horizontal Vanes plac'd a little aslope to the Wind, which being blown round, turn'd an endless Screw in the Center, which help'd to move the Wings, to be manag'd by the Person by this means rais'd aloft. . . .

. . . .

Soon after the beginning of the ROYAL SOCIETY, *viz.* about *April* 1661. a Debate arose in the Society, occasion'd by a small Tract Printed in 1660. about the cause of the rising of Water in slender Glass Pipes, higher than in larger, and that in a certain proportion to their Bores; this Discourse was wrote and Publish'd by *Hooke;* the Explication of which difficult *Phænomenon* made him the more regarded. The sum of his Reasonings upon this Subject he Publish'd afterward, *Micrography Observ.* the 6th. in which there are several very curious and then new Remarks and Hints; as to the Nature of Fluidity and Gravity, which last is farther prosecuted in his Treatise of Springs, with other excellent Subjects, to which the Inquisitive are referr'd for a more ample satisfaction.

This, together with his former Performances, made him much respected by the *R. Society,* and on the fifth of *November* 1662. "Sir *Robert Moray* propos'd a Person that was willing to be entertain'd as a *Curator* by the *Society,* offering to furnish them every day when they met, with three or four considerable Experiments; which Proposition was unanimously receiv'd, Mr. *Hooke* being nam'd to be the Person; and accordingly the next Day of their meeting on the twelfth of *November* he was unanimously accepted and taken as *Curator,* with the Thanks of the *Society* order'd to Mr. *Boyle* for dispensing with him for their use, and order'd that Mr. *Hooke* should come and sit among them, and both bring in every Day three or four of his own Experiments, and take care of such others as should be recommended to him by the *Society*."

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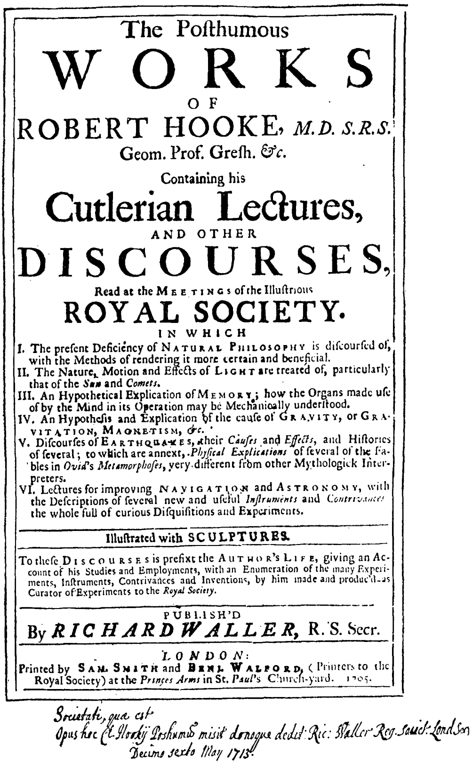
[1] From Hooke's diary.



The Poſthumous

WORKS

OF

ROBERT HOOKE, *M.D. S.R.S.*

Geom. Prof. Greſh. &c.

Containing his

Cutlerian Lectures,

AND OTHER

DISCOURSES,

Read at the MEETINGS of the Illuſtrious

ROYAL SOCIETY.

IN WHICH

I. The preſent Deficiency of NATURAL PHILOSOPHY is diſcourſed of, with the Methods of rendering it more certain and beneficial.

II. The Nature, Motion and Effects of LIGHT are treated of, particularly that of the *Sun* and *Comets*.

III. An Hypothetical Explication of MEMORY; how the Organs made uſe of by the Mind in its Operation may be Mechanically underſtood.

IV. An Hypotheſis and Explication of the cauſe of GRAVITY, or GRAVITATION, MAGNETISM, &c.

V. Diſcourſes of EARTHQUAKES, their *Cauſes* and *Effects*, and Hiſtories of ſeveral; to which are annext, *Phyſical Explications* of ſeveral of the Fables in *Ovid*'s *Metamorphoſes*, very different from other Mythologick Interpreters.

VI. Lectures for improving NAVIGATION and ASTRONOMY, with the Deſcriptions of ſeveral new and uſeful *Inſtruments* and *Contrivances* the whole full of curious Diſquiſitions and Experiments.

Illuſtrated with SCULPTURES.

To theſe DISCOURSES is prefixt the AUTHOR'S LIFE, giving an Account of his Studies and Employments, with an Enumeration of the many Experiments, Inſtruments, Contrivances and Inventions, by him made and produc'd as Curator of Experiments to the *Royal Society*.

PUBLISH'D

By ***RICHARD WALLER***, R. S. Secr.

LONDON:

Printed by SAM. SMITH and BENJ. WALFORD, (Printers to the Royal Society) at the *Princes Arms* in St. *Paul*'s Church-yard. 1705.

Societati, quæ est
Opus hoc Cl. Hookij Posthumũ misit donoque dedit: Ric: Waller Reg. Societ: Lond. Secr
Decimo sexto May 1713.

FIG. 5.

From this time the *Societies* Journals gave sufficient Testimonials of his Performances, all which would be too many to particularize here, therefore I shall only touch upon some of the chief. . . .

. . . .

At several Meetings of the *Society* in 1663, and 4. he produc'd his Microscopical Observations, and read the Explications and Discourses made upon them, which were after publish'd in his *Micrographia*, at the beginning of the year 1665.

. . . .

"Sir *John Cutler* having founded a Lecture, and settl'd an Annual Stipend upon *Robert Hooke*, M.A. of fifty Pounds during Life (entrusting the President, Council and Fellows of the said *Society* to direct and appoint the said Mr. *Hooke* as to the Subject and Number of his Lectures) the *Society* order'd several of their Members to wait upon Sir *John Cutler,* with their Thanks for his particular Favour to a worthy Member, and for that Respect and Confidence he hath hereby exprest towards their whole Body, etc."[2]

. . . .

From this time he brought in almost at every Meeting Experiments, Observations, Schemes of new Instruments and Inventions, or something considerable to the advancement of Knowledge, and very frequently read his *Cutlerian* Lectures, of many whereof he publish'd, the most material parts in his Tracts Printed at different times, in Quarto, call'd *Lectures and Collections,* &c. comprizing compendiously in one continu'd Discourse, the chief Matters and Subjects handled in several Lectures.

Thus the generous Ardor with which the Royal Society was inspir'd continued 'till the Year 1665, when, by reason of the great Mortaity then reigning, they were oblig'd to desist and break up their Weekly Meetings till the fourteenth of *March* 166$\frac{5}{6}$. . . .

. . . .

The dreadful Conflagration of a great part of the City of *London* happening in the beginning of *September* 1666. brought another great hindrance to the *Societies* Proceedings; so that they were oblig'd to remove their usual place of Meeting from *Gresham College* to *Arundel* House in the *Strand,* where, by the favour of the then Duke of *Norfolk,* they prosecuted their former Inquiries, their first Meeting at *Arundel* House being on the ninth of *Jan.* 166 .

On the nineteenth of *Sep.* 1666. he produc'd a Module he had design'd for the Rebuilding of the City, with which the *Society* were very well pleas'd, and Sir *John Laurence* the then Late *Lord Major,* address'd himself to the *Society,* expressing the present *Lord Majors and Aldermens* liking thereof, as also their desire that it might be shewn to his *Majesty,* they preferring it far before the Model drawn up by the City Surveyor.

What this Model was, I cannot so well determine, but I have heard that it was design'd in it to have all the chief Streets as from *Leaden-Hall* corner to *Newgate,* and the like, to lie in an exact strait Line, and all the other cross Streets turning out of them at right Angles, all the Churches, publick Buildings, Market-places, and the like, in proper and convenient places, which, no doubt, would have added much to the Beauty and Symmetry of the whole. How this came not to be accepted of I know not, but it is probable this might contribute not a little to his being taken notice off by the Magistrates of the City, and soon after made Surveyor.

The Rebuilding of the City, according to the Act of Parliament, requiring an able Person to set out the Ground to the several Proprietors,

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[2] From the Journal of the Secretary of the Royal Society, November 9, 1664.

Mr. *Hooke* was pitch'd upon, and appointed *City-Surveyor* for that difficult Work, which being very great, took up a large proportion of his Time, to the no small hindrance of his Philosophical Disquisitions.

In this Employment he got the most part of that Estate he died possessed of, as was evident by a large Iron Chest of Money found after his Death, which had been lock'd down with the Key in it, with a date of the Time, by which it appear'd to have been so shut up for above thirty Years: In this was contain'd the greatest part of what he left behind him, which was to the value of many thousands in Gold and Silver. That he might by this place justly acquire considerable Estate, I think cannot be deny'd. . . .

. . . .

Mr. *Oldenburgh,* the then Secretary, dying in the time of the Societies Recess, 1677. Mr. *Hooke* was desir'd to take his place, and take the Minutes of what considerable Matters past, which he did on the twenty fifth of *October* 1677. and the same day produc'd his Waterpoise and shew'd the nicety thereof.

From that time he officiated in that Place, as well as his Curatorship, shewing several Experiments and Instruments in order to explain the Gravitation and Alterations in the Air by Vapours, etc. Contriving an Air-poise to shew the different specifick Gravity of the Air by a large thin ball of Glass counter-poised.

. . . .

From this time he made Microscopical Observations on *Animalcules* in Peper-water, and other Seeds steeped in Water, confirming Monsieur *Leuenhook's* Assertions, and propos'd some Improvements of Microscopes.

. . . .

Apr. 25. 1678. he shew'd an Experiment farther to explain the action of a Muscle, " which was by a Chain of small Bladders fastened together, so as by blowing into one Pipe, the whole might be successively fill'd, and by that means contracted, supposing the Fibres of the Muscles which seem'd like a Necklace of Pearl in the Microscope, might be fill'd with a very agill Matter, which he thought most likely to be Air, which being included in so thin Skins, was easily wrought upon by Heat, Cold, or the acting Properties of the Liquors that pass between them, and so perform the lengthening and contracting of the Muscles.

Aug. 1678. he read several Discourses, and shew'd Experiments in order to confirm his Theory of Springs and springy Bodies. . . .

. . . .

Thus I have mention'd some of his Performances. . . . It must be confessed that the latter part of his Life was nothing near so fruitful of Inventions as the former; tho' it is certain he had a design to repeat the most part of his Experiments, and finish the Accounts, Observations and Deductions from them, and had an Order for the Societies bearing the Charge thereof, in *June* 1696. when he propos'd likewise to perfect the Description of all the Instruments he had at any time contriv'd; but by reason of his increasing Weakness and a general Decay, he was absolutely unable to perform it, had he desir'd it never so much.

. . . .

Thus he liv'd a dying Life for a considerable time, being more than a Year very infirm, and such as might be call'd Bed-rid for the greatest part, tho' indeed he seldom all the time went to Bed. . . . being emaciated to the utmost, his Strength wholly worn out, he dy'd on the third of *March* $170\frac{2}{3}$. being 67 Years, 7 Months, and 13 Days Old.

His Corps was decently and handsomely interr'd in the Church of St. *Hellen* in *London,* all the Members of the Royal Society then in Town attending his Body to the Grave, paying the Respect due to his extraordinary Merit.

As to his Person he was but despicable, being very crooked, tho' I have heard from himself, and others, that he was strait till about 16 Years of Age when he first grew awry, by frequent practicing with a Turn-Lath, and the like incurvating Exercises, being but of a thin weak habit of Body, which increas'd as he grew older, so as to be very remarkable at last: This made him but low of Stature. . . . He went stooping and very fast (till his weakness a few Years before his Death hindred him) having but a light Body to carry, and a great deal of Spirits and Activity, especially in his Youth.

He was of an active, restless, indefatigable Genius even almost to the last, and always slept little to his Death, seldom going to Sleep till two three, or four a Clock in the Morning, and seldomer to Bed, often continuing his Studies all Night, and taking a short Nap in the Day. His Temper was Melancholy, Mistrustful and Jealous, which more increas'd upon him with his Years. He was in the beginning of his being made known to the Learned, very communicative of his Philosophical Discoveries and Inventions, till some Accidents made him to a Crime close and reserv'd. He laid the cause upon some Persons, challenging his Discoveries for their own, taking occasion from his Hints to perfect what he had not; which made him say he would suggest nothing till he had time to perfect it himself, which has been the Reason that many things are lost, which he affirm'd he knew. He had a piercing Judgment into the Dispositions of others, and would sometimes give shrewd Guesses and smart Characters.

. . . .

It must be confess'd that very many of his Inventions were never brought to the perfection they were capable of, nor put in practice till some other Person either Foreigner or of our own Nation cultivated the Invention, which, when Hooke found, it put him upon the finishing that which otherwise possibly might have lain 'till this time in its first

Defects: Whether this mistake arose from the multiplicity of his Business which did not allow him a sufficient time, or from the fertility of his Invention which hurry'd him on, in the quest of new Entertainments, neglecting the former Discoveries when he was once satisfied of the feazableness and certainty of them, tho' there wanted some small matter to render their use more practicable and general, I know not. . . .

Whatever the answer may be, Hooke's first and best known work, the Micrographia, at once epitomizes the versatility of his genius as well as his apparent inability to see one problem through to a finish. To quote from a review of the work in the *Philosophical Transactions*, No. 2, Monday, April 3, 1665:

The Ingenious and knowing Author of this *Treatise*, Mr. *Robert Hook*, considering with himself, of what importance a faithful *History of Nature* is to the establishing of a solid Systeme of *Natural Philosophy*, and what advantage *Experimental* and *Mechanical* knowledge hath over the Philosophy of *discourse* and *disputation*, and making it, upon that account, his constant business to bring into that vast Treasury what portion he can, hath lately published a Specimen of his abilities in this kind of study, which certainly is very welcome to the Learned and Inquisitive world, both for the *New discoveries* in *Nature*, and the *New Inventions* of *Art*.

. . . .

To this end, he hath made a very curious *Survey* of all kinds of bodies, beginning with the *Point of a Needle*, and proceeding to the *Microscopical* view of the *Edges of Rasors, Fine Lawn, Tabby, Watered Silks, Glass-canes, Glass-drops, Fiery Sparks, Fantastical Colours, Metaline Colours, the Figures of Sand, Gravel in Urine, Diamonds in Flints, Frozen Figures, the Kettering Stone, Charcoal, Wood and other Bodies petrified, the Pores of Cork, and of other substances, Vegetables growing on blighted Leaves, Blew mould and Mushroms, Sponges, and other Fibrous Bodies, Sea-weed, the Surfaces of some Leaves, the stinging points of a Nettle, Cowage, the Beard of a wild Oate, the seed of the Corn-violet, as also of Tyme, Poppy and Purslane.* He continues to describe *Hair, the scales of a Soal, the sting of a Bee, Feathers* in general, and in particular those of *Peacocks; the feet of Flies; & other Insects; the Wings and Head of a Fly; the Teeth of a Snail; the Eggs of Silk-worms; the Blue Fly; a water Insect; the Tufted Gnat; a White Moth; the Shepherds-spider; the Hunting Spider, the Ant; the wandring Mite; the Crab-like insect, the Book-worm, the Flea, the Louse, Mites, Vine-mites.* He concludeth with taking occasion to discourse of two or three very considerable subjects, viz. *The inflexion of the Rays of Lights in the Air; the Fixt starrs; the Moon.*

In representing these particulars to the Readers view, the Author hath not only given proof of his singular skil in delineating all sorts of Bodies (he having drawn all the *Schemes* of these 60 *Microscopical* objects with his own hand) & of his extraordinary care of having them so curiously engraven by the Masters of that Art; but he hath also suggested in the several reflexions, made upon these Objects, such conjecturs, as are likely to excite and quicken the Philosophicall heads to very noble contemplations. Here are found inquiries concerning the *Propagation of Light* through differing mediums; concerning *Gravity;* concerning the *Roundness* of Fruits, stones, and divers artificial bodies; concerning *Springiness* and *Tenacity;* concerning the *Original* of *Fountains;* concerning the *dissolution of Bodies into Liquors;* concerning *Filtration,* and the ascent of Juices in Vegetables, and the use of their *Pores.* Here an attempt is made of solving the strange *Phænomena of Glass-drops;* experiments are alleged to prove the *Expansion* of *Glass* by heat, and the *Contraction* of *heated-Glass* upon cooling; *Des Cartes* his *Hypothesis of colours* is examined: the *cause of Colours,* most likely to the Author, is explained: Reasons are produced, that *Reflection* is not necessary to produce *colours,* nor a *double refraction:* some considerable *Hypotheses* are *offered,* for the explication of Light by Motion; for the producing of all colors by Refraction; for reducing all sorts of colors to two only, *Yellow* and *Blew;* for making the *Air,* a dissolvent of all *Combustible Bodies:* and for the explicating of all the regular figures of *Salt,* where he alleges many notable instances of the *Mathematicks* of *Nature,* as having even in those things which we account vile, rude and coorse, shewed abundance of curiosity and excellent *Geometry* and *Mechanism.* And here he opens a large field for inquiries, and proposeth Models for prosecuting them. . . .

He goes on to offer his thoughts about the Pores of bodies, and a *kind* of *Valves* in wood; about spontaneous generation arising from the Putrefaction of bodies; about the nature of the Vegetation of mold, mushromes, moss, spunges; to the last of which he scarce finds any Body like it in texture. He adds, from the naturall contrivance, that is found in the leaf of a Nettle, how the stinging pain is created, and thence takes occasion to discourse of the poysoning of Darts. He subjoyns a curious description of the shape, *Mechanism* and use of the *sting* of a *Bee;* and shews the admirable Providence of Nature in the contrivance and fabrick of *Feathers* for Flying. He delivers those particulars about the Figure, parts and use of the head, feet, and wings of a Fly, that are not common. He observes the various wayes of the generations of Insects, and discourses handsomely of the means, by which they seem to act so prudently. He taketh notice of the *Mechanical* reason of the *Spider's* Fabrick, and maketh pretty Observations on the hunting Spider, and other Spiders and their Webs. And what he notes of a Flea, Louse, Mites and Vinegar-worms, cannot but exceedingly please the curious Reader.

Having dispatched these Matters, the Author offers his Thoughts for the explicating of many *Phænomena* of the Air, from the *Inflexion,* or from a *Multiplicate Refraction* of the rays of Light within the Body of the *Atmosphere,* and not from a *Refraction* caused by any terminating *superficies* of the Air above, nor from any such exactly defin'd *superficies* within the body of the *Atmosphere.* . . .

He concludeth with two *Celestial Observations;* whereof the *one* imports, what multitudes of Stars are discoverable by the Telescope, and the variety of their magnitudes . . . the other affords a description of a *Vale* in the *Moon,* compared with that of *Hevelius* and *Ricciolo;* where the Reader will find several curious and pleasant Annotations . . . about the variations in the *Moon,* and its *gravitating* principle, together with the use, that may be made of this Instance of a gravity in the *Moon.*

As to the *Inventions of Art,* described in this Book, the curious Reader will there find these following:

1. A *Baroscope,* or an Instrument to shew all the Minute Variations in the *Pressure of the Air;* by which he affirms, that he finds, that before and during the time of rainy weather, the Pressure of the Air is less. . . .
2. A *Hygroscope,* or an Instrument, whereby the *Watery steams,* volatile in the Air, are discerned, which the Nose it self is not able to find. Which is by him full described in the Observations touching the *Beard of a wild Oate,* by the means whereof this Instrument is contrived.
3. An Instrument for *graduating Thermometers,* to make them *Standards* of *Heat* and *Cold.*
4. A *New Engin* for *Grinding Optik Glasses,* by means of which he hopes, that any Spherical Glasses, of what length soever, may be speedily made. . . .
5. A *New Instrument,* by which the *Refraction* of all kinds of Liquors may be exactly measured, thereby to give the Curious an opportunity of making Trials of that kind, to establish the *Laws of Refraction.* . . .

Lastly, this Author despairs not that there may be found many Mechanical Inventions, to improve our Senses of *Hearing, Smelling, Tasting, Touching,* as well as we have improved that of *Seeing* by *Optick Glasses.*

Thus the "Micrographia" is obviously something more than "Some Physiological Descriptions of Minute Bodies made by Magnifying Glasses"—it is a demonstration of the advantages to be gained by the use of artificial devices of precision in studying nature. The book is replete with singular anticipations of later discoveries and inventions by other workers and "it will hardly be deny'd that there are more excellent Philosophical Discoveries and Hints, than in most extant of its bulk.'' It contains the first study of the '' fantastical colours'' of thin plates with a partial explanation by interference; a theory of light as a ''very short vibrating motion'' transverse to straight lines of propagation through a ''homogenous medium'' (p. 56). Heat is stated to be ''a property of a body arising from the motion or agitation of its parts'' (p. 37); Fluidity is ''but an effect of a very strong and quick shaking motion, whereby the parts are, as it were, loosened from each other, and consequently leave an interjacent space or vacuity'' (p. 41); while ideas in regard to combustion are clearly outlined (p. 103) which foreshadow those reached by Mayow.

But the biologist's interest in the ''Micrographia'' is chiefly in Hooke's application of his improved compound microscope (Fig. 2) to the study of animals and plants. At this time Malpighi, Grew, Leeuwenhoek and Swammerdam were engaged in studies, with simple lenses or compound microscopes, on the secrets of the finer structure of organisms which were to give them higher rank in biological history than Hooke's desultory work in this field. Hooke, as has been said, was interested primarily in demonstrating the usefulness of his microscope and his belief that in inventions for the ''improvement of the senses'' lay the key to a more profound understanding of nature. This he accomplished and therefore, entirely aside from the other remarkable qualities of the ''Micrographia,'' the book holds a unique place in the history of biology. It paved the way, as it were, for the more special, profound and methodical studies of the contemporary founders of the morphology of organisms by creating a considerable interest in microscopy, and in addition proved to be for over a century the standard source from which writers on the microscope gleaned much information and many figures.[3]

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[3] E. g., L. Joblot, 2d Ed., 1754; H. Baker, 1742; M. F. Ledermüller, 1760–1763; etc. In 1745 Baker reprinted and explained the plates of the Micrographia.

Among the large variety of observations made by Hooke, which are cited in Oldenburg's review just quoted in extenso, one in particular claims the attention of the biologist. This is "Observation XVIII. Of the Schematisme or Texture of Cork, and of the Cells and Pores of some other such frothy Bodies." Here are clearly described for the first time the "little boxes or cells" of organic structure, and his use of the word "cell" is responsible for its application to the protoplasmic units of modern biology. This observation, together with the plate, is presented in facsimile in Figs. 3 and 4. In Hooke's treatise on "The method of Improving Natural Philosophy," included in the volume of his posthumous works (p. 28), this observation on cells is selected by Hooke to illustrate his method of scientific inquiry.

Again, "Observation XXV. Of the stinging points and juice of Nettles, and some other Venomous Plants" is accompanied by a figure of the lower side of a nettle leaf in which the outlines of the epidermal cells are well delineated and, as Miall remarks, "there is something very like a nucleus in one of them, but this may be accidental." However, Hooke did not recognize any relationship between the structures he observed in the nettle and in the cork.

As an appendix to his observations on cork, the author relates some experiments on Mimosa in which he attributes the "motion of this Plant upon touching . . . to a constant *intercourse* betwixt every part of this Plant and its root, either by a *circulation* of its liquor, or a constant pressing of the subtiler parts of it to every extremity of the Plant"—a partial anticipation of the modern idea of turgescence (cf. Figs. 3 and 4). The "Observation on Petrify'd wood and other Petrify'd bodies" is interesting because the author takes quite a modern point of view in regard to fossils (cf. Fig 4, Part I).

And so we might continue—but as the reviewer remarks in the *Journal des Scavans,* December, 1666: "This Book contains more than can be taken notice of in an

Extract,'' and we conclude the survey of this man of the past still using the words of the past:

> All his Errors and Blemishes, were more than made amends for, by the Greatness and Extent of his natural and acquired Parts, and more than common, if not wonderful Sagacity, in diving into the most hidden Secrets of Nature, and in contriving proper Methods of forcing her to confess the Truth, by driving and pursuing the *Proteus* thro' all her Changes, to her last and utmost Recesses; so that what *Ovid* said of *Pythagoras* may not unfittly be apply'd to him.
>
> *Mente Deos adiit, et quae Natura negavit*
> *Visibus humanis, oculis ea Pectoris hausit.*
>
> There needs no other Proof for this than the great number of Experiments he made, with the Contrivances for them, amounting to some hundreds; his new and useful Instruments and Inventions, which were numerous, his admirable Facility and Clearness, in explaining the Phænomena of Nature, and demonstrating his Assertions; his happy Talent in adapting Theories to the Phænomena observ'd, and contriving easy and plain, not pompous and amusing Experiments to back and prove those Theories; proceeding from Observations to Theories, and from Theories to farther trials, which he often asserted to be the most proper method to succeed in the interpretation of Nature. For these, his happy Qualifications, he was much respected by the most learned Philosophers both at home and abroad: And as with all his Failures, he may be reckon'd among the great Men of the last Age, so had he been free from them, possibly, he might have stood in the Front. But *humanum est errare.*[4]

[4] Waller, *op. cit.*